(12) UK Patent Application (19) GB (11) 2 195 659 (13) A

(43) Application published 13 Apr 1988

(21) Application No 8621004

(22) Date of filing 29 Aug 1986

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(51) INT CL[4]
C25B 1/10

(52) Domestic classification (Edition J):
C7B 146 235 282 758 CAX

(56) Documents cited
GB A 2155952

(58) Field of search
C7B
Selected US specifications from IPC sub-class C25B

(54) Energy conversion apparatus

(57) Apparatus for converting mechanical motive power (e.g. from a windmill) into fuel (e.g. hydrogen) by way generating electricity for the electrolysis of an electrolyte into constituents including a fuel gas comprises an electrolysis chamber 12 having electrodes 18, 20 operable by the application of electric current thereto to decompose an electrolyte within the chamber into its constituents, the electrolyte having a fuel gas e.g. hydrogen as a substantial constituent, means for separating 22 and collecting 13 the fuel gas, and means for generating the current electromagnetically including a stator assembly 32 comprising conductors carried in or on wall structure of the chamber and operatively connected to one of the electrodes, a rotor 34 or other carrier assembly guided for movement relative to the stator assembly and carrying a plurality of magnetic poles 38 in coacting relationship to the conductors for the current generation, and means 44, 46 for applying motive power in use for movement of the carrier assembly.

Heat derived from the operation of the generator passes to the electrolyte for improved efficiency, the gas pressurisation of the electrolyte also adds to efficiency, and devices may be included for automatic regulation of the current applied at the electrodes and for over-load protection of the generating means.

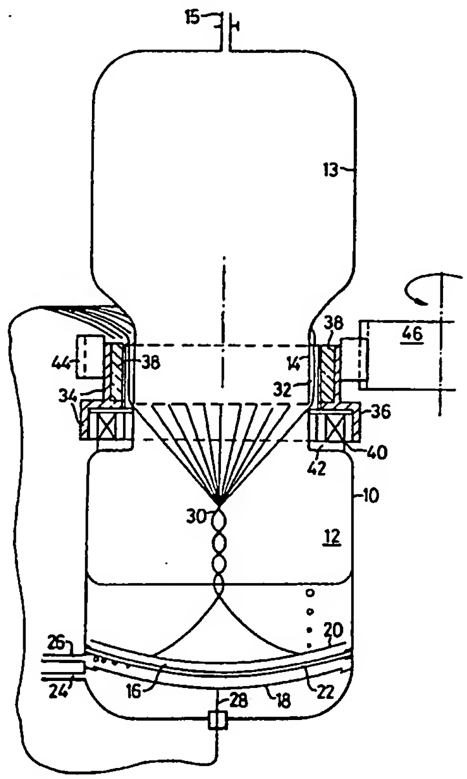

Fig. 1

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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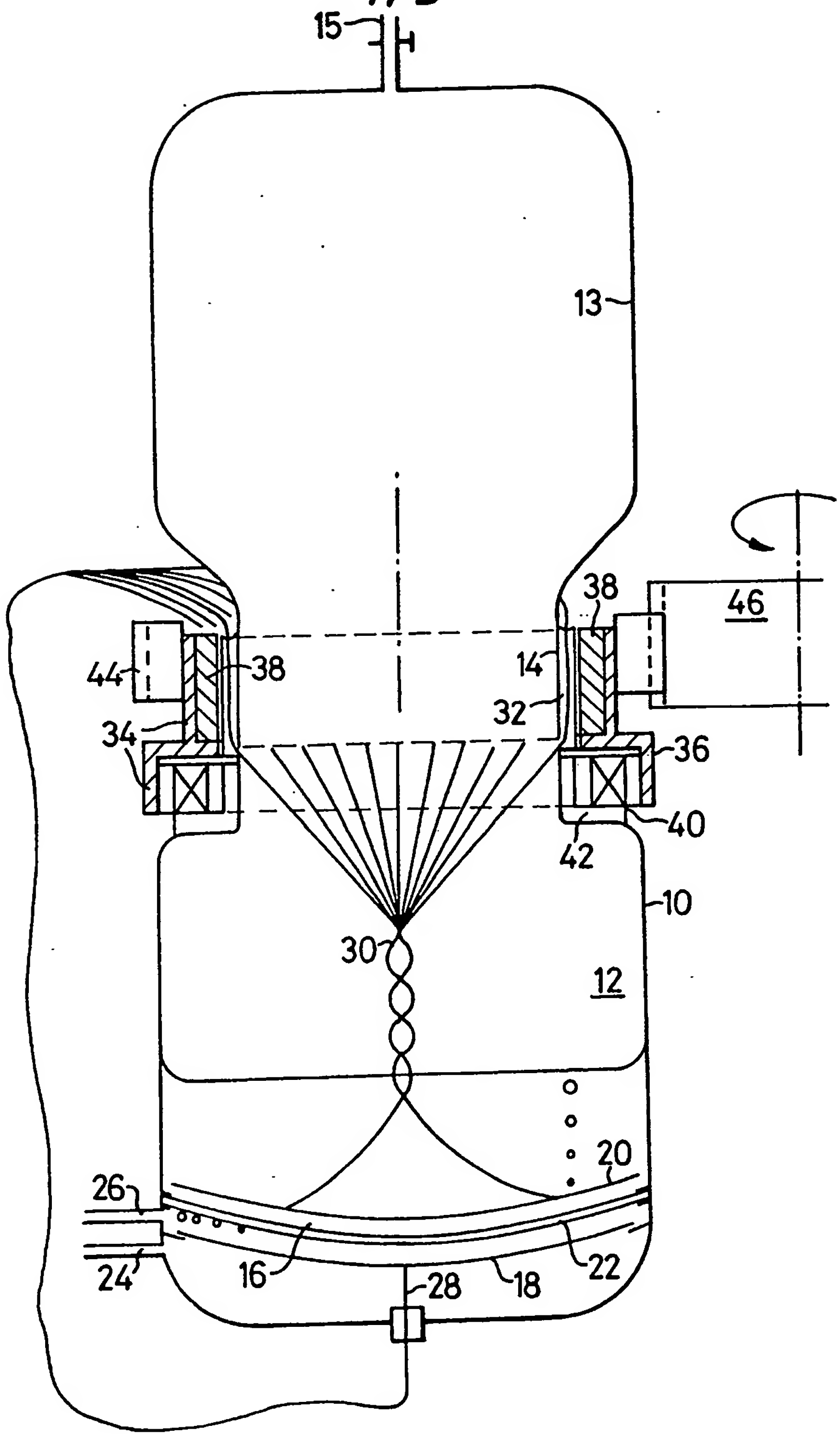

Fig. 1

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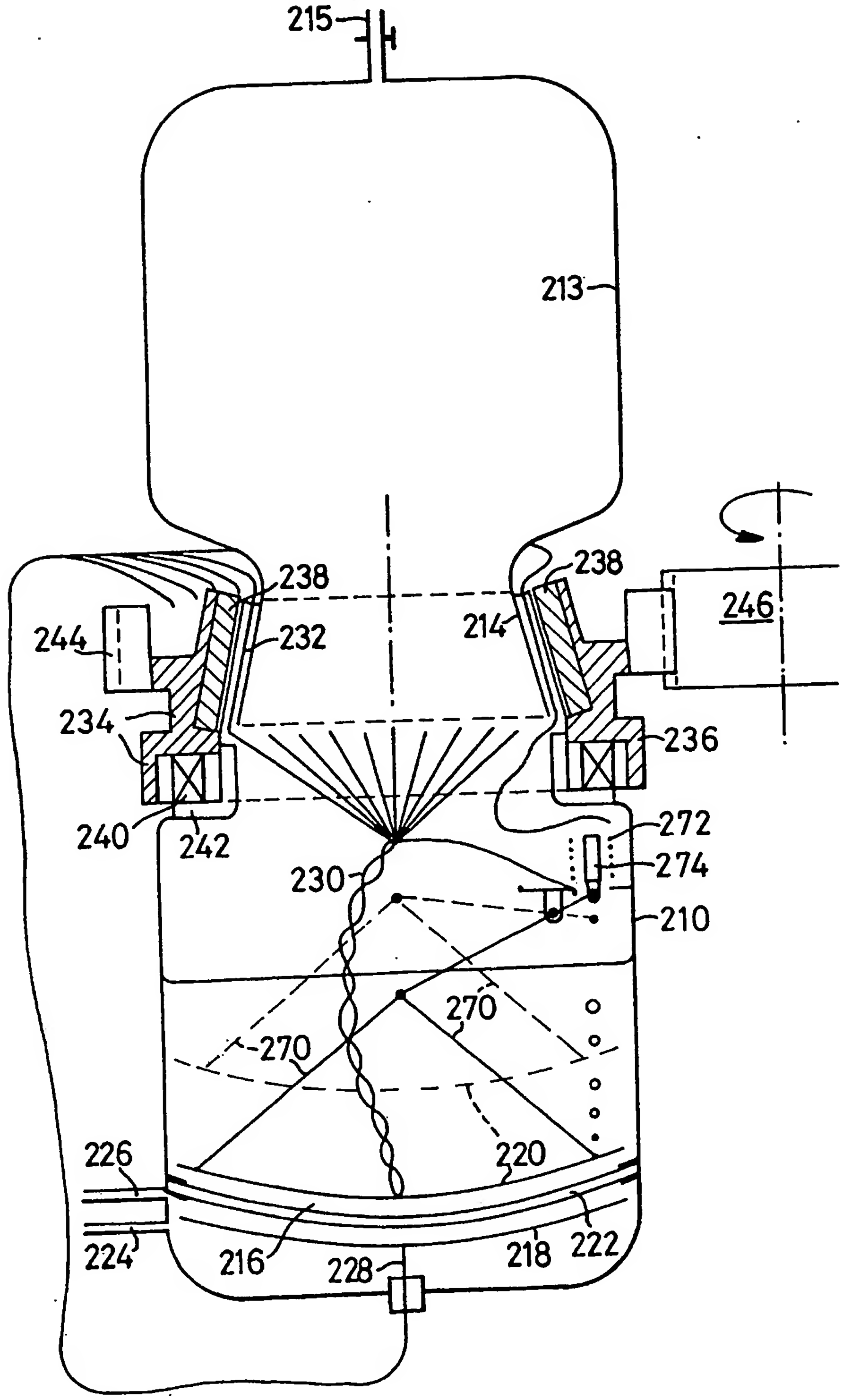

Fig. 2

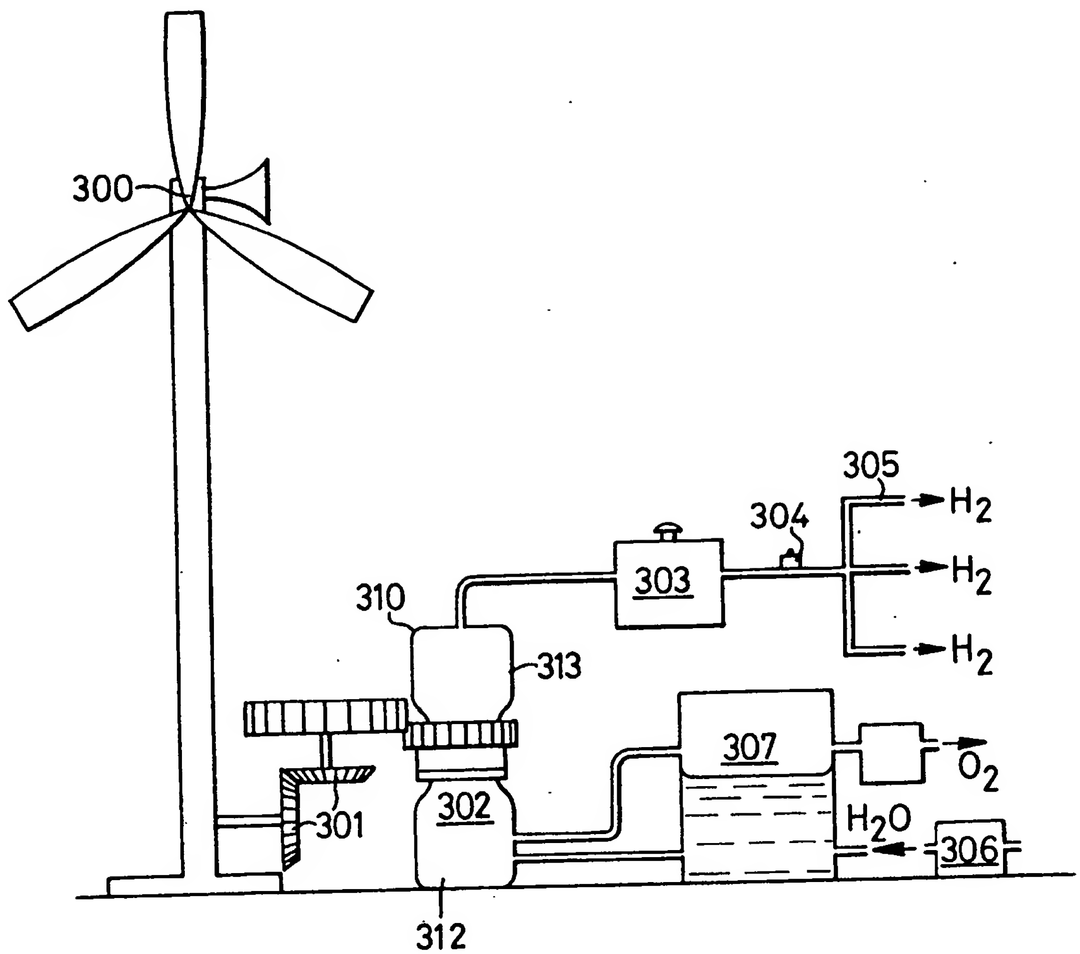

Fig. 3

SPECIFICATION

Energy conversion apparatus

This invention relates to apparatus for converting energy, in particular the conversion of mechanical motive power to a readily stored and transported fuel by way of generating electricity for the electrolysis of an electrolyte, typically water, into constituents including a gas fuel, typically hydrogen, which can be pressurised and stored, distributed or transported as and when required for use.

There have been various proposals for electrolytic production of hydrogen but these have generally been plants operating industrially on a substantial scale with high input of energy e.g. using mains A.C. power which is converted to D.C. (with resulting energy losses and inefficiency) for the electrolysis process.

There have also been proposals for using such renewable but fluctuating energy sources as wind, wave, tidal, or solar power in combination with electrolysis for energy conversion and storage but again such proposals have hitherto been on a substantially large scale involving complex and high cost plant.

The object of the present invention is to provide energy conversion apparatus which is particularly economical to manufacture and run and which is capable of high efficiency operation even using small scale plant. A further object is the provision of such plant which is compact, light in weight, readily transported an installed even in remote locations, adaptable in use, and which will operate reliably over a long term with a minimum of maintenance and servicing.

According to one aspect of the invention there is provided energy conversion apparatus comprising an enclosed electrolysis chamber having electrode means operable by the application of electric current thereto to decompose an electrolyte within the chamber into its constituents, the electrolyte being selected from those having a fuel gas as a substantial constituent, means for separating and collecting said fuel gas, and means for generating said current electromagnetically including a stator assembly comprising a plurality of conductors carried in or on wall structure of the chamber and operatively connected to the electrode means, a rotor or other carrier assembly guided for movement relative to the stator assembly and carrying a plurality of magnetic poles in coacting relationship to said conductors for said current generation, and means for applying motive power in use for movement of the carrier assembly.

Conveniently the conductors are disposed equi-angularly about a cylindrical zone of said wall structure and the carrier assembly is an annular rotor journalled co-axially with the stator assembly and rotatably driven by the motive power.

According to another aspect of the invention there is provided energy conversion apparatus in which a supply of hydrogen gas fuel is produced by electrolysis of water using electric current generated by the application of motive power to a magneto electric machine characterised in that said machine is formed as an integral or intimately related part of structure defining one or more chambers or cells in which the electrolysis takes place whereby heating of the machine during operation serves to raise the temperature of the chambers or cells for increased efficiency of the electrolysis process.

Preferably the electrolysis chamber(s) or cell(s) is or are self pressurising in that the collected hydrogen or other fuel gas is accumulated in a reservoir to maintain a pressure substantially in excess of atmospheric pressure, again increasing the efficiency of the electrolysis process.

It is also preferred, particularly where a variable or fluctuating motive power, e.g. wind power, is used that provision is made for automatically regulating the current applied at the electrode means at or around an optimum level for greatest efficiency. Conveniently this is achieved by varying the positioning of some one or more of anode and cathode elements of the electrode means as a function of the power input.

In one example of the latter arrangement a servo actuator eg a solenoid or other electromagnetic actuator, is connected to respond to the generated current output and is mechanically linked to one of the electrode elements, e.g. the cathode to shift the latter proportionally to changes in the current level.

It is also preferred that provision against over-loading is included, for example by generation of excess current producing repulsive forces which cause the magnet poles to be displaced to increase spacing from the conductors of the stator assembly.

The apparartus may comprise a generally cylindrical pressure vessel with its axis vertical, an upper portion thereof serving as a reservoir in which the hydrogen or other gas fuel is accumulated under pressure, its lowermost portion serving as the electrolysis chamber and a reduced diameter waist connecting said portions incorporating the generator stator assembly with the rotor disposed co-axially therearound. The electrode means may comprise anode and cathode plates in the form of dished discs mounted across the electrolysis chamber in spaced relationship to each other and with their concave faces directed upwardly. The anode is lowermost and a dished membrane is positioned between the electrodes to separate the gases produced in operation, in the case of water oxygen will accumulate below the membrane as it leaves the anode, the dished shape directing the bubbles to the radially outer edges of the membrane

from which the oxygen is led off while the hydrogen bubbles leave the cathode to pass upwards into the accumulating reservoir.

Examples of the invention are now more particularly described with reference to and as shown in the accompanying drawings, wherein:—

Figure 1 is a vertical section of a first form of electrolytic energy conversion apparatus;

Figure 2 is a like section of another form of said apparatus; and

Figure 3 is a diagrammatic general view of a wind powered energy conversion apparatus.

Referring firstly to Fig. 1 the embodiment of the invention there shown is a small scale integrated unit for production of pressurised hydrogen fuel by electrolysis of water, the energy source being any convenient motive power such as wind or water power or even possibly human or animal muscle power.

It is further contemplated that the units could utilise off-peak or surplus electricity by being provided with electric driving motors brought into operation when appropriate; or could utilise mechanical energy which would otherwise be wasted arising from the braking of machines such as locomotives or other vehicles, the hydrogen produced being stored until a suitable disposal point is reached or possibly utilised for auxiliary services on the vehicle or the like eg heating a railway train.

The apparatus comprises a generally cylindrical pressure vessel 10, typically formed of metal and preferably either nickle-plated at least in a lower region which contains an alkaline electrolyte referred to hereafter. The vessel is designed to withstand gas pressures of up to several atmospheres. In use it is mounted with its axis vertical and is shaped to define a lowermost electrolysis chamber 12, and an upper hydrogen accumulator or reservoir 13, the vessel having a reduced diameter waisted region 14 between chamber 12 and reservoir 13.

Extending across chamber 12 is an electrode assembly 16 comprising an anode 18, a cathode 20 above and in spaced parallel relationship to the anode and a membrane 22 which extends in spaced relationship between the anode and cathode.

The anode, cathode and membrane are all dished with their concave faces directed upwardly and they are located and positioned on locating formations about half-way up the inner wall structure of chamber 12.

The anode and cathode may each be made of metal mesh, typically of nickel or nickel-plated and they may be coated or otherwise treated with electrolytically active components. Their shaping and construction and their positioning and spacing from each other within the chamber are designed to maximise the efficiency of the electrolysis process by providing optimum conductivity and rapid discharge of gas bubbles.

The membrane 22 prevents the passage of gas bubbles and thereby keeps the oxygen and hydrogen generated at the anode 18 and cathode 20 respectively separate while permitting the electrical inter-activity between the members of the electrode assembly and the passage of ions in solution in the liquid between the anode and cathode. Suitable material for forming membrane 22 such as asbestos based compounds or combinations of polytetrofuoroethylene and oxide such as zirconium dioxide are known in the art.

In operation the electrode assembly 16 is immmersed in a strong alkaline solution for example 15–45% KOH or 15–45% NaOH. These alkalis are not consumed in the electrolytic process but serve simply to give high electrical conductivity in the temperature range 20–120°C.

An inlet duct 24 connects with a lowermost region of chamber 12 below the electrode assembly for input of water, preferably demineralised, to replace that consumed by the process and an oxygen outlet duct 26 leads from the chamber on a level with the outer edge of the lower face of membrane 22, the dished shape of the electrode assembly ensuring that oxygen bubbles leaving anode 18 float radially outwards below the lower face of membrane 22 to collect at the highest outer margin thereof for discharge. The oxygen may pass into a secondary chamber (not shown) which may be associated with the water supply to ensure correct pressure control.

Bubbles of hydrogen generated on the cathode 20 float freely upwards without obstruction to leave the surface of the liquid electrolyte and fill the upper region of chamber 10 and the reservoir 13, pressure therein building up as the hydrogen accumulates.

A supply of D.C. current is applied to the electrodes from generating means which forms an integral part of the unit. A first conductor lead 28 is connected to anode 18 and passes through a fluid and pressure tight gland in the base of the vessel 10. Further conductor leads 30 are connected to the cathode 20 and pass upwards through the central region of chamber 12 and then through pressure seals at equi-angular positions around the lower part of the cylindrical wall of the waisted region 14, said conductors being insulated from each other and from the vessel walls by suitable resin based and/or ceramic dielectric materials. Said conductors are continued upwardly in equi-angular spaced parallel relationship and in an axial direction along the exterior of the wall of region 14 to constitute a stator assembly 32 of the current generating means, conveniently these parallel parts of the conductors run in an annular cavity or series of cavities and the latter may be filled with a resin based or other insulating compound.

Disposed coaxially with the stator assembly 32 and in close surrounding relationship

thereto is a rotor assembly 34 comprising a supporting ring 36 carrying a plurality of permanent magnets 38 at equi-angular positions with closely spaced like poles directed radially inwardly to coact with the conductors of the stator assembly 32.

Ring 36 is provided with roller bearings 40 for low friction engagement with an annular track 42 carried on the outside of the stator assembly 32 and the ring is provided with radially outwardly directed gear teeth 44 whereby rotary drive is transmitted thereto e.g. through an intermediate gear 46 of a gear train or other transmission arrangement for applying motive power to the rotor assembly. It will be appreciated that various forms of power transmission can be employed, e.g. bevel or other gearing, endless belts or chains or the like.

The upper ends of the stator conductors are led away externally to complete the circuit by connection to the lead 28 to anode 18.

The number of magnets 38 and coacting conductors of the stator and the diameter and spacing thereof are selected for optimum current generation having regard to the speed and level of motive power available.

It has been found in practice that the current requirement for most effective electrolysis of water should give an anode to cathode voltage drop of around 1.4–2.2 Volts under practical conditions having regard to the need to overcome electrode polarisation and resistance in the circuit, and current densities of up to 1 amp per cem^2 of electrode surface area.

During generation of current as described above it is anticipated that due to inevitable inefficiences in the construction of the generating means, particularly as it is desired that it should be as simple as possible for economy, durability and ease of maintenance and repair, some heat will be generated which would normally represent an unrecovered energy loss. In the present construction a substantial proportion of such heat, which will tend to arise mostly in the stator assembly 32, is directly transmitted to the metal walls of the chamber 12 so as to raise the operating temperature of the electrolyte. The exterior of the vessel walls, e.g. in the region of chamber 12, may be thermally insulated to enhance this effect. It is known that the efficiency of an electrolytic cell increases substantially as its temperature is raised and this heating is therefore utilised to increase the efficiency of the energy conversion.

The efficiency of the process is also increased as the pressure within vessel 10 builds up during accumulation of the hydrogen gas therewithin. Once the safe working pressure of the system has been reached the hydrogen gas is preferably discharged automatically e.g. through a relief valve 15 into other reservoirs or vessels and/or is piped directly away when required for use e.g. as a fuel for cooking, heating or a multitude of purposes.

It is anticipated that the arrangement shown in Fig. 1 in schematic form using suitable magnets and effective current production will electrolyse water at a rate of around 0.5 kw. The energy conversion rate at given temperature and pressure is substantially defined by the geometry of the electrode assembly, in this example an electrode surface area of around 300 cm^2 is contemplated with an operating voltage thereat of 1.4–1.8 v, the resistance of the electrode assembly (spacing of anode and cathode and electrical characteristics of the separating membrane) being preferably arranged to give this voltage.

The motive power input will very commonly be irregular and variable, e.g. where wind power is employed though fluctuations can be minimised by suitable choice and mechanical control of the windmill e.g. one having automatically variable geometry blades responsive to wind pressures.

To avoid risk of de-magnetising the permanent magnets 38 if a sudden surge of power produces a strong induced magnetic field in the stator conductors, magnets with suitably high coercities or energy product values may be selected and/or a safety provision may be built in to the drive mechanism to ensure that power is applied in a controlled manner for slow and regular acceleration of the rotor.

A second embodiment of the invention is shown diagrammatically in Fig. 2 and is a modification of that shown in Fig. 1, equivalent parts having the same reference numbers prefixed by 2.

In this arrangement pressure vessel 210 has a waisted region 214 in the form of a truncated upwardly tapering cone. Thus, the stator assembly 232 of the generating means decreases in overall diameter from the bottom to the top.

The rotor assembly 234 has the poles of the magnets 238 inclinded to correspond to the angle of the stator conductors and the rotatably driven ring 236 carrying the magnets is guided for vertical upward displacement relative to the stator assembly 232. The length of the gear teeth 244 of ring 236 are lengthened axially so that they remain in mesh with the input drive train throughout the range of vertical movement of the ring.

This arrangement provides automatic overload protection e.g. if the drive train should be subjected to sudden power and speed surges, in that the repulsive magnetic forces induced in the stator conductors will repel the poles of magnets 238 causing rotor assembly 234 to rise in its guides, so increasing the spacing between the magnet poles and the conductors and thus reducing the overloading effect. As the induced magnetic field disperses the rotor assembly will drop back to its normal operating position.

This arrangement may also provide a means

of adjusting the torque and speed settings for a given power input, e.g. the positioning of the magnets may be selectively pre-set to regulate the spacing between the magnets and the conductor wires during running, as by limiting the maximum upward displacement of rotor assembly 234.

The embodiment of Fig. 2 also incorporates further provision for accommodating varying power input automatically while maintaining the efficient operation of the electrolysis process by keeping the operative current level at the cathode and anode at around the desired optimum.

The anode 218 and the separating membrane 222 of the electrode assembly 216 are shaped and mounted as described with reference to Fig. 1, current from one side of the generator means being fed to anode 218 by conductor lead 228.

However, instead of being mounted at a fixed position in electrolysis chamber 212 the cathode 220 is suspended from arms of pivoted lever links 270 for rising and falling movement within chamber 212 so that the relative spacing of cathode 220 from membrane 222 and the anode 218 can be selectively varied.

This spacing is controlled automatically by a servo device responsive to the current level being produced by the generator means. While various mechanical/electrical devices can be employed, in this particular example the servo device comprises a solenoid coil 272 whose windings are connected in series between the generator stator conductors and the output connection leads 230 to the cathode 220. Coil 272 is mounted at a fixed position and co-acts with the movable magnet 274 pivotally connected to lever links 270.

When the output current from the generator means is at a low level magnet 274 acts as a counterweight urging lever arm 270 upwards to the position shown in broken lines in Fig. 2 so that the cathode 212 is raised to maximum spacing from the membrane and anode 218 is also shown in broken lines in Fig. 2. If the power output from the generator means increases substantially the added energisation of coil 272 draws magnet 274 upwards so urging the cathode 220 downwards, at maximum current output it will be at its lowest position in close relationship to anode 218.

The theory behind this operation is as follows. Assuming that the cathode and anode are at close relative spacing to operate in an optimum manner at a given high power rating and that the power is then reduce to 30% of the previous level with said spacing remaining unchanged. The current at the anode and cathode will fall by a corresponding proportion and, by the operation of Ohm's Law, the voltage will drop correspondingly and may well fall below the critical voltage needed for production of hydrogen of around 1.6 volts. All the power output from the generating means would then be dissipated in resistive heating. In the arrangement described above increasing the relative spacing between anode and cathode increases the resistance and therefore maintains the resistivity at the level needed to maintain the critical voltage and continue hydrogen production.

Energy conversion plant incorporating the invention may take a wide variety of forms dependent, for example, on the required capacity of the plant, on whether it is a permanent fixed installation or a mobile or semi-permanent apparatus, and/or on the form and rating of the motive power available. One example of a small scale wind power plant is illustrated schematically in Fig. 3.

A windmill 300 is coupled by a mechanical transmission 301 to drive the generating means of an electrolysis plant 302 as described with reference to Fig. 2 above. The hydrogen accumulating in the reservoir portion 313 of the pressure vessel 310 of the plant is led to a supplementary pressure storage tank 303 and thence through a suitable pressure reducing and governing valve 304 at service pressure through ducts 305 to wherever it is required for use e.g. as a fuel for cooking, heating etc. A demineralised water supply 306 is connected to an infeed device 307 operating in conjunction with the pressurised oxygen output to maintain the water level in the electrolysis chamber 312 as previously described.

A single windmill or other motive power source may be used to drive a number of electrolysis units in common.

A further example could have the arms or blades of a windmill, water turbine or the like carried on the rotor support ring 36 (Fig. 1) itself, either as a vertical axis machine or as a horizontal axis machine if the central part of the device (14 in Fig. 1) were turned through 90%.

CLAIMS

1. Energy conversion apparatus comprising an enclosed electrolysis chamber having electrode means operable by the application of electric current thereto to decompose an electrolyte within the chamber into its constituents, the electrolyte being selected from those having a fuel gas as a substantial consituent, means for separating and collecting said fuel gas, and means for generating said current electromagnetically including a stator assembly comprising a plurality of conductors carried in or on wall structure of the chamber and operatively connected to the electrode means, a rotor or other carrier assembly guided for movement relative to the stator assembly and carrying a pluralitu of magnetic poles in coacting relationship to said conductors for said current generation, and means for applying motive power in use for movement of the carrier assembly.

2. Apparatus as in Claim 1 wherein the conductors are disposed equi-angularly about a cylindrical zone of said wall structure and the carrier assembly is an annular rotor journalled co-axially with the stator assembly and rotatably driven by the motive power.

3. Apparatus as in Claim 1 or 2 wherein the electrolysis chamber is self-pressurising in that the collected fuel gas is accumulated to maintain a pressure in the chamber substantially in excess of atmospheric pressure.

4. Apparatus as in Claim 1, 2 or 3 including provision for automatically regulating the current applied at the electrode means at or around an optimum level for greatest efficiency.

5. Apparatus as in Claim 4 wherein said automatic regulation is effected by means for varying the relative positioning of anode and cathode elements of the electrode means as a function of the power input.

8. Apparatus as in Claim 5 including a servo actuator connected to respond to the generated current output and linked to one of the electrode elements for shifting the latter proportionally to changes in the current level.

7. Apparatus as in any preceding claim including means for automatic over-load protection of the generating means.

8. Apparatus as in Claim 7 wherein said over-load protection means include means allowing the magnet poles to be displaced relative to the conductors of the stator assembly to increase their spacing from the latter under repulsive forces due to the generation of excess current.

9. Apparatus as in any preceding claim in which the electrolyte operatively decomposed is water, the fuel gas collected being hydrogen.

10. Apparatus as in any preceding claim comprising a generally cylindrical pressure vessel with its axis operatively vertical, an upper portion thereof serving as a reservoir in which the hydrogen or other gas fuel is accumulated under pressure, its lowermost portion serving as the electrolysis chamber, and reduced diameter waist connecting said portions incorporating the generator stator assembly with the rotor disposed co-axially therearound.

11. Apparatus as in any preceding claim wherein the electrode means comprises anode and cathode plates in the form of dished discs mounted across the electrolysis chamber in spaced relationship to each other and with their concave faces directed upwardly.

12. Apparatus as in Claim 11 wherein the anode plate is lowermost and a dished membrane is positioned between the electrode plates to separate the gases produced in operation whereby, when the electrolyte decomposed is water, oxygen will accumulate below the radially outer edges of the membrane as it leaves the anode while hydrogen will leave the cathode to pass upwards for accumulation above the electrolyic.

13. Energy conversion aparatus in which a supply of hydrogen gas fuel is produced by electrolysis of water using electric current generated by the application of motive power to a magneto electric machine characterised in that said machine is formed as an integral or intimately related part of structure defining one or more chambers or cells in which the electrolysis takes place whereby heating of the machine during operation serves to raise the temperature of the chambers or cells for increased efficiency of the electrolysis process.

14. Energy conversion apparatus substantially as hereinbefore described with reference to and as shown in Figs. 1, 2 and/or 3 of the accompanying drawings.

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